Reefkeepers' Monitoring of Artificial Reefs: An Example of Local Citizen Science Involving Recreational Divers and Others on Southeast Vancouver Island

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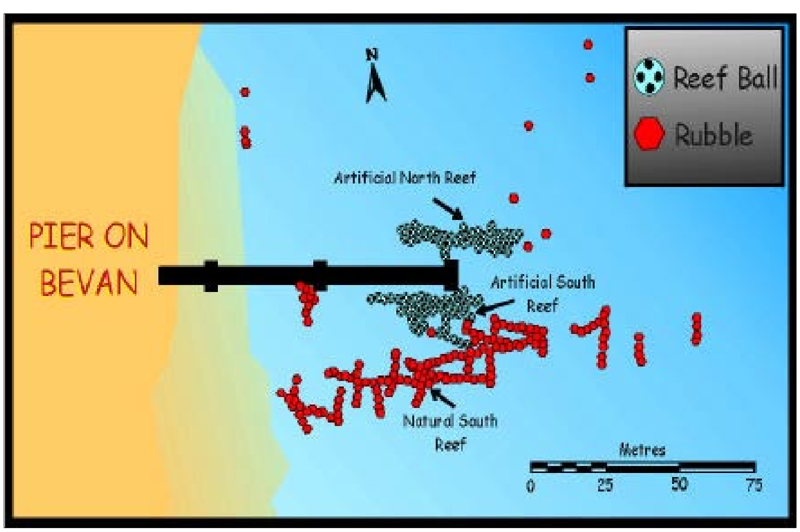
Abstract
In 1996, the Township of Sidney near Victoria on Vancouver Island built a 90m long waterfront pier for seascape viewing and recreational fishing. Regulatory agencies required the Township to provide compensation for habitat lost to the pier. Two artificial reefs using pre-formed concrete structures called Reefballs were constructed beside the pier to address this requirement, and also to promote community participation, sports diving and economic development. The pier and reefs attracted support from researchers, schools, media, developers and tourists alike, partly because this was the first application of such reef technology in northeast Pacific Ocean temperate waters.

To monitor the effectiveness of these artificial reefs, community leaders approached biologists at the Institute of Ocean Sciences, a local research facility of federal Department of Fisheries and Oceans. Without sufficient resources for such diver-intensive projects, the Institute began working collaboratively with the Royal British Columbia Museum and others to design and manage a project called Sidney Pier Artificial Reef Science (SPARS). This project involved volunteer time and in-kind contributions especially from specially trained recreational divers who conducted systematic surveys. Stemming from this local project is a broader DFO citizen science initiative called Reefkeepers that deals with subtidal monitoring protocols, information handling systems and community stewardship approaches. We report here on our recent interpretation of the SPARS dataset gathered from 1997 to 2001. Biases affecting data quality and utility are discussed here, as well as patterns of artificial reef colonization and recommended applications of such community-based science in coastal decision-making.

Introduction
In 1996, the Town of Sidney near Victoria on Vancouver Island built a 90m long waterfront pier for seascape viewing and recreational fishing. Regulatory agencies required the Town to provide compensation for habitat lost to the pier. To address this requirement, two 3m x 30m linear artificial reefs were constructed in 10 m water depth, using 320 pre-formed, hollow concrete "igloos" structures called Reefballs™ . Taken from Harper et al (1998a), the schematic map below depicts these reefs and pier.



These structures were one of the first Reefball reefs installed in temperate NE Pacific waters. The pier and reefs attracted considerable interest and support from researchers, schools, media, developers and tourists alike, partly because this was the first application of such reef technology in northeast Pacific Ocean temperate waters. The Reefball Foundation promotes them largely in tropical coral seas.

To monitor the effectiveness of these artificial reefs, community leaders approached biologists at the Institute of Ocean Sciences, a local research facility of federal Department of Fisheries and Oceans. Without sufficient resources for such diver-intensive projects, the Institute began working collaboratively with the Royal British Columbia Museum and others to design and manage a project called Sidney Pier Artificial Reef Science (SPARS).

Approach and Objectives

This project involved volunteer time and in-kind contributions especially from recruited recreational divers who were trained to carry out routine, systematic surveys. Stemming from this local project is a broader DFO citizen science initiative called Reefkeepers dealing with subtidal monitoring protocols, information handling systems and community stewardship approaches. The Reefkeepers Guide (Conley et al. 2000) provides step-by-step instructions, not only for dive surveys but also for project set-up, course training, dive safety and data archiving. The survey method chosen is a fixed swath along a permanent transect, swum by paired divers looking for selected species. The divers record the species abundance and distribution on their dive slates, during several passes of required duration. Data entry and reporting by a project data manager are facilitated by a custom IBM/PC MSAccess application called ARKS (A Reef Keepers System).

Burd and Smiley (2002) verified, analysed and interpreted the SPARS data gathered from 1997 to 2001. Over 90 people participated in the project, 28 of which were volunteer sports divers who have taken one or more training workshops, and who conducted one or more surveys. One third of the divers were PADI Divemasters and Instructors, and three were professional marine biologists and museum curators. Five divers conducted 12 or more surveys.

Results

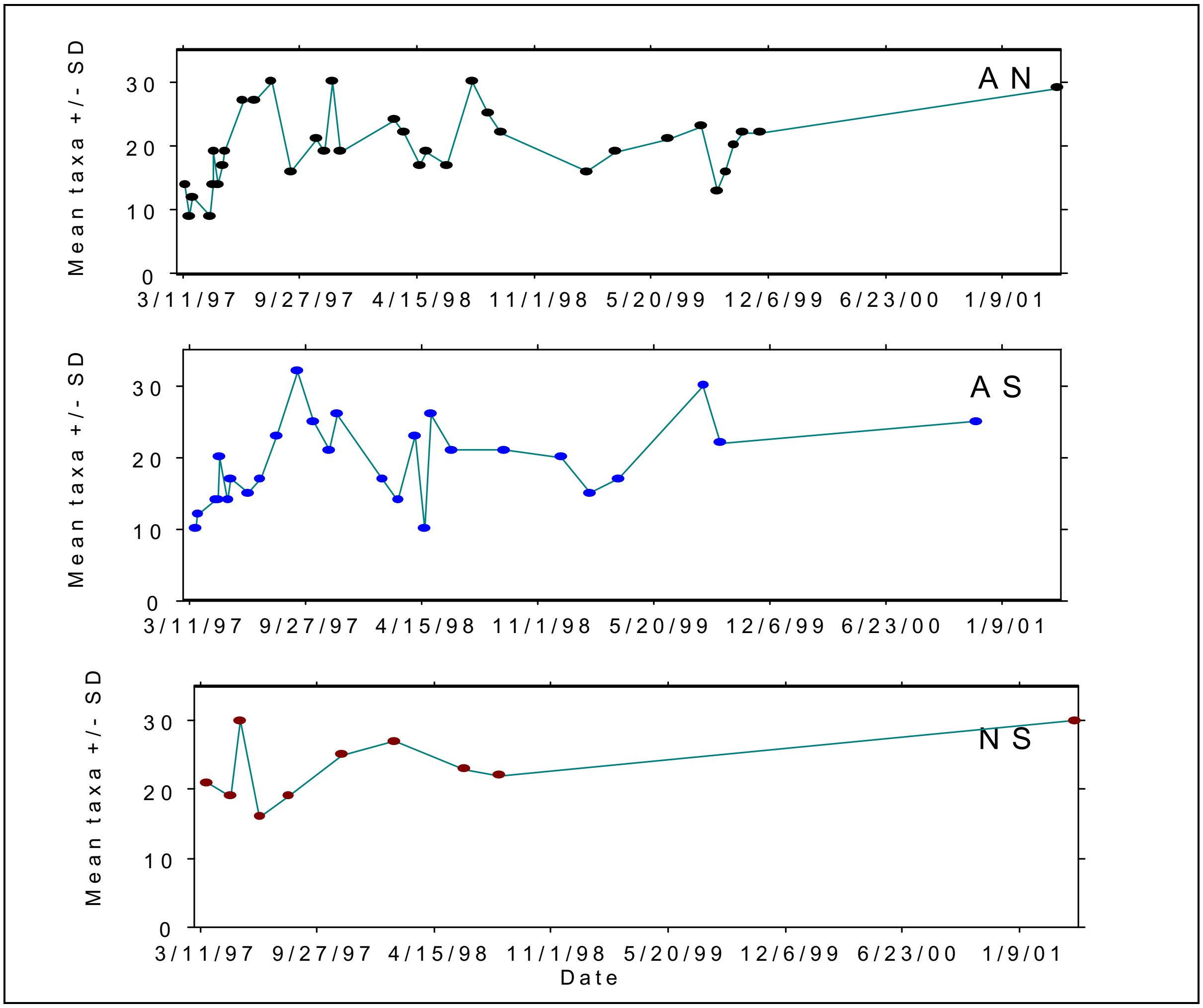
To varying degrees, Burd and Smiley (2002) examined and evaluated the SPARS dataset in terms of rate of artificial reef colonization, trends in species richness and abundance, survey biases due to diver expertise, differences between artificial and natural reefs, and the effects of water properties and adjacent habitats. The following text and figures are a few highlights taken from this publication, and intended to illustrate some typical “thrills and spills” of a citizen science project such as SPARS.

Over a period of about four years (March 1997 – April 2001), the divers carried out about 130 surveys, most of which were paired. Depending on the reef, they conducted 16 to 61 surveys on 10 to 35 dates over a period of 1490 days. Most of their effort was directed towards the two artificial reefs called Artificial North and Artificial South, and less so towards an adjacent natural reef known as Natural South. More than 5,000 minutes of observations were logged, and twelve videos archived for collaboration.

The divers searched specifically for about 90 species within both fish and invertebrate taxonomic groups: rockfishes (7), surfperch (4), greenling and lingcod (3), stickleback and tubesnout (2), herring and smelt (3), pipefish (1), sculpins (5), lumpsucker and clingfish (2), gunnels and pricklebacks (1), sole (1), gobies (2), shrimp (1), crabs (9), barnacles (1), sponges (1), sea anemones (2), plume worms (2), nudibranchs (15), chitons (4), scallops and oysters (1), snails (4), seastars and brittlestars (8), sea cucumbers (4) and sea squirts (4). The numbers in brackets indicate number of species.

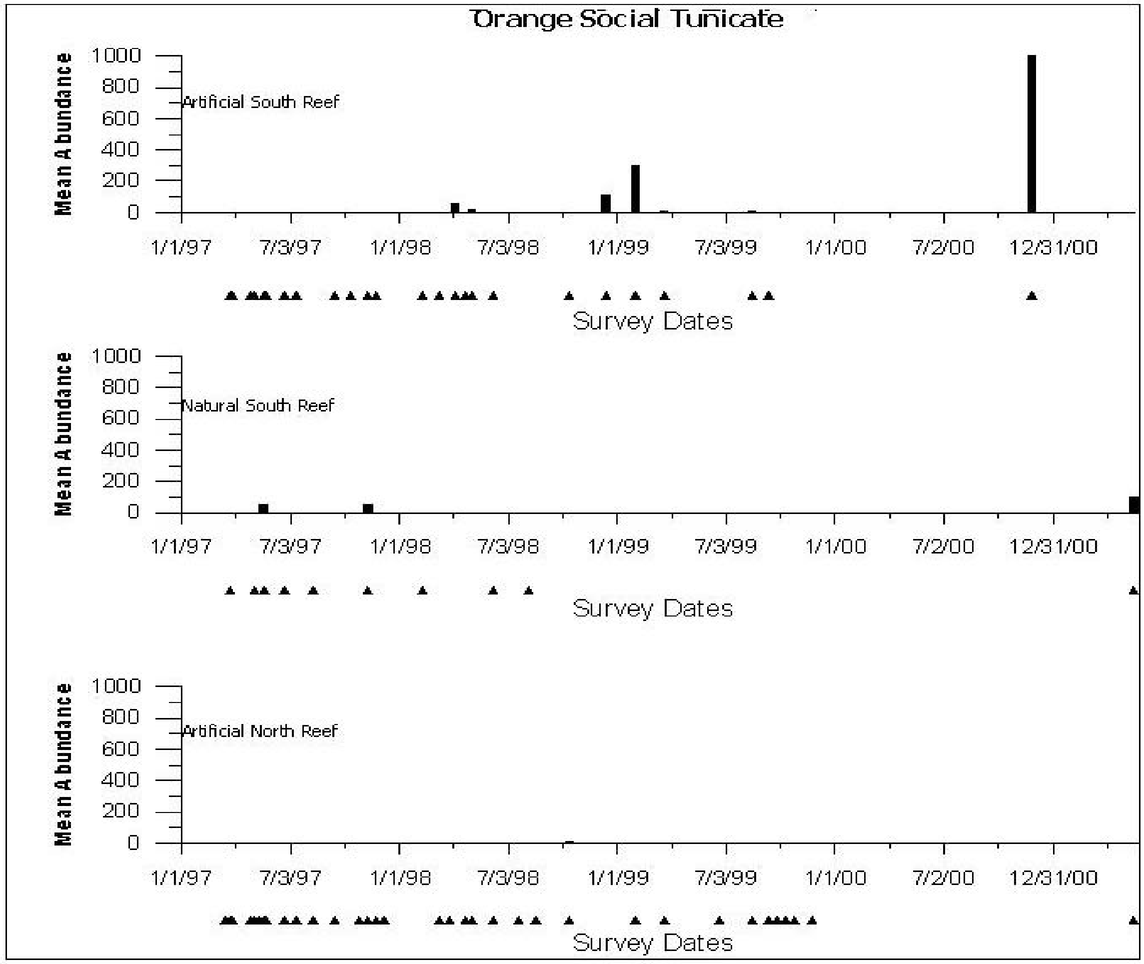
As one source of bias and error, most inexperienced divers usually saw fewer taxa, but some recorded considerably more taxa, than the professional biologists. Twelve percent of pair-diver surveys had unacceptable sampling precision, based on total abundance analyses. The counting method used was most accurate for large, easily visible taxa in numbers less than 20 individuals per reef. For more abundant or colonial forms, the method of counting was a logarithmic ranking. Counts of “Many” (10-100) and “Abundant” (>1000) were more subjective, since divers stopped counting after about 20, and started estimating.

Nevertheless, whether all diver observations are or are not aggregated, the data reveal that the natural variability of species abundance was considerable on all three reefs. Even after four years, the community variability of artificial reefs remained indeterminate. However, the artificial reef communities achieved a normal range of variability within 18 months of construction, as expressed by total number of taxa (15-30), mean number of taxa (12-24) and mean abundance (80-300). Statistical analysis of the presence/absence and abundance data showed that the artificial reefs were most similar to each other, but still significantly distinct with high power. The graph below illustrates such similarities and differences.



On Artificial South Reef in particular, the high abundances in the last survey are attributed to a few opportunistic taxa (acorn barnacles, rock oyster) and colonial animals such as orange social tunicate (see the graph below). An overshoot of opportunists such as this was expected, but much earlier than 3 ½ years after deployment of the reef balls. This suggests that at least one of the artificial reefs had not yet reached a stable community composition.

Careful scrutiny of the videos suggested algal cover was more intense and protracted in winter 1997 through spring 1998, during an El Niño event, than in following years. Some species such as the orange social tunicate were found only south of the pier, on both the natural and artificial reefs. The perch species and tubesnout were virtually absent from natural reef, and rockfishes were more common on artificial reefs than the natural one. The graph on the following page illustrates this.



Orange Social Tunicate
Mean Abundance
1000
800
600
400
200
0
Artificial South Reef
1/1/97
7/3/97
1/1/98
7/3/98
1/1/99
7/3/99
1/1/00
7/2/00
12/31/00
Survey Dates
Natural South Reef
Artificial North Reef

Mean abundance of dominant taxa at each reef – SPARS 1997-2001

Barnacles	49.2	88.8	1.2
Sunflower Starfish	18.0	19.6	18.0
Tubesnout	10.9	6.0	1.1
Plumose Anemone	8.0	4.5	4.5
Striped Perch	6.2	5.8	0.0
Red Rock Crab	6.1	6.0	6.1
Northern Kelp Crab	5.0	7.8	4.4
Decorator Crab	4.1	2.9	6.1
Sponges	3.3	4.2	15.9
Sharp-nosed Crab	2.9	1.6	6.6
Orange Social Tunicate	0.4	62.8	20.0
Rock Oyster	0.1	22.5	0.0
Kelp Crab	3.8	5.0	2.9
Purple or Ochre Seastar	3.6	2.9	3.9
Copper Rockfish	3.4	3.3	2.9
Gunnels and Pricklebacks	2.9	1.5	5.0
Orange Sea Cucumber	0.0	0.0	39.8

Refer to Burd and Smiley (2002) for more details including possible explanations for these and other trends.

Conclusions and Recommendations

Burd and Smiley (2002) offer recommendations that stem from the lessons learned and the analyses performed. The following are key ones.

1. Carefully select and identify the taxa.
   - Improve identification of rockfishes (*Sebastes* spp.).
   - Omit non-reef dwellers from the taxa list.
   - Reduce the number of taxa surveyed.
   - Offer more rigorous training in species identification.
2. Further reduce diver bias.
   - Ensure post-dive debriefing to identify discrepancies.
   - Enter extra habitat and behavioural details into logs.
   - Take video footage to assist species recognition.
3. Refine the survey methods.
   - Ensure more routine sampling such as monthly or bimonthly surveys.
   - Recruit expert research divers for data comparison.
   - Survey a nearby natural reef to serve as a reference.
   - Always use underwater lights to aid searching and identifying.
   - Distinguish between juvenile and non-juvenile fish and crabs.
   - Insist on fixed survey time and distance.
   - Emphasize percent cover as counting strategy for sessiles.
   - Consider estimating abundance of rooted algae from videos.

4. Better manage the data.
    - Devote more effort to data standardization, after dives and entering data.
    - Record carefully the dive conditions such as visibility.
    - Test the divers periodically to assess identification and counting techniques.

As a final perspective, we believe that recreational divers, given training and co-ordination, are some of our community's best candidates for citizen scientists.

This is because they:
- Enjoy repetitive dives for monitoring trends.
- Come fully prepared with gear and equipment.
- Work as buddies for safety and collaboration.
- Dive largely to see marine life and to log observations.
- Are stimulated by broader research objectives.
- Bring local knowledge and first hand experiences.
- Like the challenge of mastering new protocols.
- Appreciate learning from biologists, and sharing insights with them.
- Ready to tell others such as school children and the media.
- Make the hard work fun and enjoyable.

Acknowledgements

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References Cited

Burd, B.J., and Smiley, B.D. 2002. SPARS - Sidney Pier Artificial Reef Science: Qualitative and quantitative analyses of volunteer diver monitoring over four years. (In Preparation) Canadian Technical Report of Fisheries and Aquatic Sciences.

Conley, K.W., Cosgrove, J.A., Lambert, P., and Smiley, B.D. 2000. The Reefkeepers Guide for monitoring subtidal habitats of Canada's Pacific waters. (In Preparation) Fisheries and Oceans Canada, Pacific Region. Modules 1, 2, 3, 4, and 5.

Harper, J.R., Emmett, B., Howes, D.E. and McCullough, D. 1998a. Seabed imaging and mapping system - seabed classification of substrate, epiflora and epifauna. *In* Proceedings of the 1998 Canadian Hydrographic Conference, Victoria, BC, 13p.

The Reefkeepers and SPARS logos